A New Steel Solution for Short Span ABC Bridge Replacements in Massachusetts

By: Thomas G. Zink

The Massachusetts Department of Transportation (MassDOT) has proven once again that innovative thinking and the willingness to incorporate new technologies into a bridge program can lead to the successful acceleration of a bridge replacement project.

As an industry leader in the use of Accelerated Bridge Construction (ABC) technology, MassDOT chose to replace a small bridge carrying River Road over Ironstone Brook in the Town of Uxbridge, Worcester County with a folded steel plate girder structure. The first application of its kind, folded steel plate girders are fabricated from a single steel plate of uniform thickness that is then bent along multiple lines using a hydraulic metal press break to form an inverted tub shaped section. A patented system applicable for spans up to 60-ft in length, this type of fabrication eliminates costly details and processes that have made steel alternatives less competitive than other materials for short span bridges. The need for welding is significantly reduced, and the stability of the resulting girder shape eliminates the need for both internal and external cross framing.

Uxbridge, is a town in south central Massachusetts, 40 miles south west of Boston, near the Rhode Island border which was first settled in 1662, incorporated in 1727, and named for the Earl of Uxbridge in England. The town's motto is "Weaving a Tapestry of Early America". This harkens to the textile industry which developed in the early 1800's along the lines of the Rhode Island System, a labor and production model characterized by hydro driven textile mills, family employment including children as young as age 7, company homes, company stores and Sunday school education where the children learned to read and write.

Photo 1: Former bridge supporting River Road over Ironstone Brook.

The former two span bridge was constructed in 1900 and reconstructed in 1930. It consisted of an 18 inch deep reinforced concrete slab supported by stone masonry gravity abutments and a reinforced concrete wall pier located in the waterway. Located on an urban local off-system roadway with an ADT of approximately 3,300 vehicles, the bridge carried two lanes of traffic with no shoulders and measured approximately 26'-9" in total width and approximately 32-ft in length. The former bridge railing consisted of guiderail supported by steel pipe posts bolted to the concrete slab. The profile within the project vicinity is relatively flat, and the roadway crosses the waterway with no skew. Based on previous inspections, the substructure was determined to be in "serious" condition due to the deterioration of the mortar surrounding the abutment masonry. Combined with its substandard geometry and safety features, MassDOT decided that a full structure replacement was in order.

In March of 2009, Gannett Fleming, Inc. was selected by MassDOT to serve as the consulting engineer of record for the replacement structure. During preliminary design, it was determined that the new bridge would be constructed wider to accommodate a 12-ft lane and 4-ft shoulder in each direction. It was also determined that the new bridge would consist of a single span with substructures placed behind the masonry abutments to minimize disturbance to the waterway. The new structure would therefore be approximately 50-ft in length and 35-ft in width and provide a 42-ft wide hydraulic opening between the new abutments. In addition, the limited space on site would necessitate the complete closure of the roadway throughout the duration of construction, resulting in a 4.5 mile detour. It was therefore decided that the proposed structure type would need to be compatible with current Accelerated Bridge Construction (ABC) practices to minimize the duration of the detour.

Several alternatives were investigated as part of the MassDOT Type Study Selection process, including adjacent precast concrete box beams, steel multi-stringers, and a concrete arch frame. However, the characteristics present at this particular site were also compatible with an experimental system developed by the University of Nebraska-Lincoln consisting of folded steel plate girders. In November of 2009, MassDOT decided to utilize this project as a pilot for such construction, and Highway Bridge Services, LLC of Lincoln, Nebraska was brought on board to perform the design of the girders and provide assistance to Gannett Fleming for the inclusion of details and specifications into the bid documents.

Photo 2: Erection of a prefabricated superstructure module.

To accelerate construction, the design utilized four (4) 50-ft long, 24" deep folded steel plate girders, each prefabricated with a 6.5" deep, 4 ksi concrete deck section attached using 3/4" diameter end welded shear studs. Each beam utilized a single 0.50" thick, 50 ksi steel plate measuring 50-ft in length and 106" in width. These dimensions were critical to ensure that the multiple bends could be made using a standard press break. After bending them to the required shape, a minimal number of welded components were then attached to the beams, including end plates, sole plates, and headed shear studs. Four bolted flange separator plates were also attached to the bottom of each girder to help maintain shape, and the entire beam was galvanized. The decks were then cast in a precast shop with the beams oriented in an upright position with falsework supporting the cantilevers. The shipping width of each interior superstructure module measured 10'-2" including headed rebars protruding 11" from each edge of the precast slab. Each exterior module was 8'-7" in width including a single edge of protruding rebar and an integral concrete curb cast along the exterior slab edge.

To further accelerate construction, the replacement bridge also incorporated precast concrete integral abutments. Each abutment consisted of four match-cast precast concrete wall sections with a 2-ft diameter void formed at the base for installation over a steel H-pile. The design also called for the use of a modular retaining wall system for the wingwalls. Formliners were specified for the exposed faces of the new substructure components in an effort to replicate the masonry patterns of the former bridge.

The bid documents were developed for this $1.7 M project which also included approximately 600-ft of roadway reconstruction in the approaches necessary to accommodate a slight alignment shift caused by the widened bridge section. The design was completed in July of 2010, and the construction contract was awarded to the John Rocchio Corporation of Smithfield, Rhode Island in October of the same year.

With the detour in place, the former bridge was demolished and the steel H-piles were installed for each of the proposed abutments. The piles were set in 2.5-ft diameter augured holes that included a 5-ft long embedment into rock. The piles were anchored to the rock using concrete, and the remainder of the void surrounding the piles was filled with crushed stone. The piles were set to template with a small (1") plan tolerance. This was necessary to ensure proper alignment with the formed pile voids at the base of each precast concrete wall panel. Four wall panels, each measuring 8'-10" wide and 4'-0" thick, were placed over the piles at each abutment location. The panels were then locked together using sixteen (16) 1" diameter bars set into transverse post tensioning ducts. Once tensioned, the ducts and anchorage block-outs were grouted, and the pile voids were filled with a 4 ksi self-consolidating concrete through metal fill sleeves cast into the wall panels. This allowed the contractor to gravity feed the anchorage concrete from the bridge seats. The contractor then installed a T-Wall type modular retaining wall system that served as the bridges wingwalls.

The four superstructure modules were delivered to the site on October 7, 2011 and erected using a 240 ton Liebherr Model LTM 1200 boom crane. Since the approach fill had not yet been placed, the crane could be positioned behind one of the new abutments without imposing any significant lateral pressure on the substructure. The superstructure modules were delivered to the site one at a time, allowing the crane to pick and place the modules with no more than a 90° swing. All four superstructure modules were delivered and erected in a single day.

Work continued by backfilling the abutments and placing embankment material while completing the T-Wall installation. The superstructure modules were then locked together using 4 ksi concrete closure pours along their longitudinal interfaces. The modules were detailed to ensure that the protruding headed rebars of one module would not interfere with the rebars of the adjacent module. Once the closure pours were constructed and

Photo 3: Completed bridge.

cured, the four modules began functioning as a unit. The backwalls and approach slabs were also constructed simultaneously with the longitudinal closure pours. The deck was then overlaid with a hot mix asphalt system, and a TL-4 metal bridge railing was installed using threaded rods protruding from the precast concrete curbs.

Bridge replacement required thirteen weeks to complete, and the roadway was opened to traffic in November of 2011. As this structure was the first folded steel plate girder bridge ever constructed and placed in service, MassDOT decided to instrument the bridge components with strain gauges to monitor stresses in the steel plates, deck, and closure pours. Performance is currently being monitored by the University of Massachusetts.

MassDOT considers this project a success since a new technology was implemented at a competitive price and resulted in a 28% reduction in on-site construction schedule when compared to a more conventional adjacent precast concrete box beam alternative. In addition, their willingness to implement an innovative structure type has opened the door to the industry to consider a steel alternative in a span range generally dominated by precast concrete solutions.

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